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BITTERBRUSH IN CALIFORNIA[1/]

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INTRODUCTION

Bitterbrush (Purshia tridentata D. C.) is one of the most important range plants in the West. It is grazed by cattle, sheep, and goats, as well as by deer, antelope, and other game animals, and the seeds are an important item in the diet of rodents and birds.

The range of bitterbrush (fig. 1) covers about 340,000,000 acres in the 11 western range States and southern British Columbia. In California bitterbrush is distributed on approximately 7,500,000 acres east of the Sierra Nevada and Cascade Mountains at altitudes ranging from 3,500 to 11,000 feet. It commonly grows on sites occupied by big sagebrush (Artemisia tridentata), ponderosa and Jeffrey pine (Pinus ponderosa and P. Jeffreyi), Sierra juniper (Juniper occidentalis), and singleleaf pinon (Pinus monophylla). Bitterbrush grows best on soils that are well-drained, moderately deep, and fine- or coarse-textured. In many places it forms most of the ground cover. It is rather intolerant of shade, and the densest stands are found in forest openings and clearings and on slopes below the pine forest.

1/ This study was furthered in many ways by the cooperation and actual participation of Region 5 personnel, more particularly, F. P. Cronemiller, F. D. Douthitt, and A. Fausett of the Division of Wildlife and Range Management, Regional Office; and numerous staff men of the eastside national forests (Shasta, Modoc, Lassen, Plumas, Tahoe, Mono, and Inyo) in analyzing bitterbrush problems in the field and in gathering data on the distribution and artificial reseeding of the plant. Comments on the manuscript by the U. S. Fish and Wildlife Service; the Forest Insect Laboratory, Bureau of Entomology and Plant Quarantine; the Department of Botany, University of California; the Forest Service, Washington, and this Station were very helpful in the preparation of this paper.

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* MAINTAINED AT BERKELEY, CALIFORNIA, IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA.

On large areas this valuable range browse has been destroyed or damaged by fire, too heavy and untimely grazing by livestock and game animals, defoliation by caterpillars, or girdling by rodents. Drought, unfavorable temperatures, and other factors of weather have in many cases made the plant more susceptible to injury. In many localities not enough reproduction is becoming established to perpetuate the stands. Over a period of years a serious decrease in range production has resulted from such damage to bitterbrush. Much critical observation was made of bitterbrush in California in past years, and the experiments here reported were begun in 1940. The object of these studies was to obtain additional facts, principally on the growth and reproduction of the species, that would be helpful in the management and rehabilitation of this browse on the ranges. The following report applies to California but some of the findings may also hold in other regions.

DESCRIPTION

Bitterbrush is a diffusely branched, deciduous shrub (fig. 2) of the rose family (Rosaceae). It is usually 2 to 6 feet tall but in some places it attains a height of 16 feet and a stem diameter of 12 inches. The leaves are 1/4 to 3/4 inch long, three-toothed on the ends, and are grouped in small bunches on the twigs and stems. The plants range in color from dark green to light gray. Different-colored plants often grow side by side. The leaves of the light-colored ones are densely covered with white matted hairs, whereas those of dark plants are almost smooth and often much smaller. On some dark plants the leaves are sticky and have a strong obnoxious resinous scent because of the presence of glandular hairs and pustule-like glands. The plant bears numerous five-petalled flowers about 3/4 inch in diameter, which grade in color from pale cream to bright yellow on different plants. The stamens, of which there are about 25, and the petals are attached to the rim of a cuplike receptacle which contains the ovary.

The plant is called quininebrush, deerbrush, buckbrush, antelope-brush, greasewood, and black sage as well as bitterbrush. In sagebrush types it stands out as a dark-colored plant. The names bitterbrush and quininebrush are appropriate because all parts of the plant, even the flowers and the wood, have a very bitter taste. The bitter substance was isolated in two pharmacological studies, but its chemical composition was not determined. It was reduced to crystalline form and was found soluble in water. It is not an alkaloid nor a glucoside. The plant was also found to contain appreciable quantities of tannin.

The young seedling (fig. 3) has cotyledons which are lobed at the base and are 3/8 to 1/2 inch long and 1/4 to 3/8 inch wide. The young stem below the cotyledons is conspicuously red. This character is an aid to recognizing the seedlings in the field. The edges of the cotyledons, the upper portion of the young stem, and the young leaves are dotted with red glandular hairs.

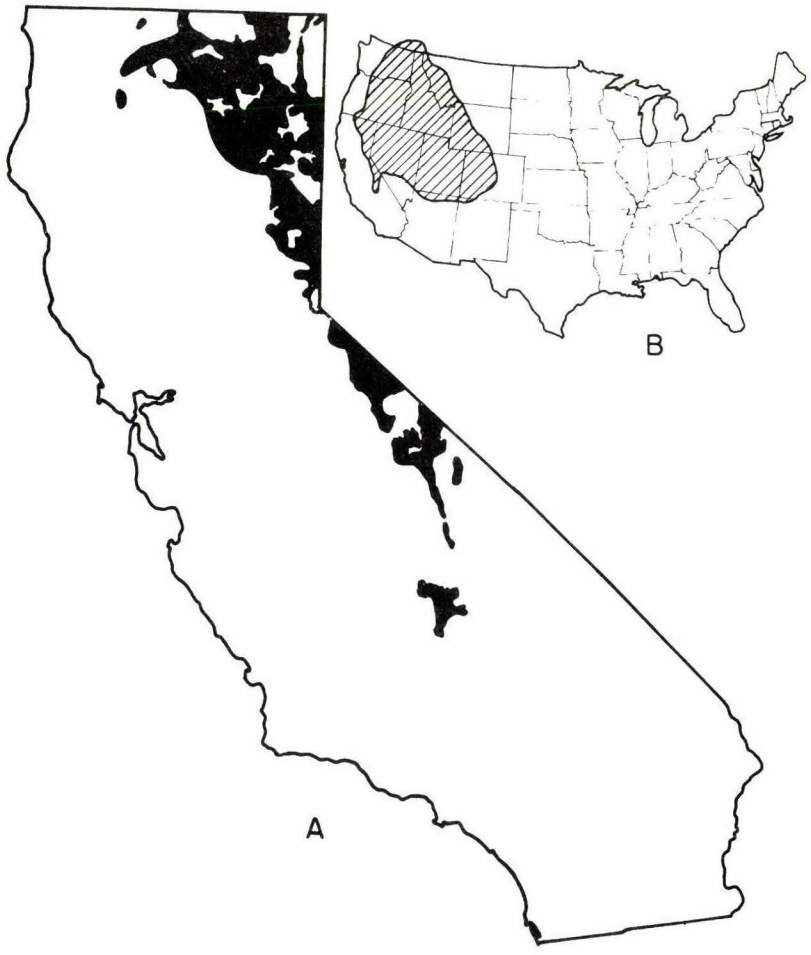

Fig. 1. General distribution of bitterbrush: A, In California; and B, in the United States and southern British Columbia. Based on information from the U. S. Forest Service, Region 5, and the Division of Dendrology and Forage Investigations, Forest Service, Washington, D. C.

Fig. 2. Characteristic form of ungrazed bitterbrush.

The seeds of bitterbrush resemble apple seeds in size and shape. They are egg-shaped, slightly flattened, and about 1/4 to 3/8 inch long. When wet they are dark reddish purple to almost black in color, but when dry they are grayish and tinged with purple and brown. The coat of the maturing seed contains a reddish purple sap which congeals into a hard granular mass when the seed is fully ripe. Each seed is enclosed in a spindle-shaped, ribbed husk about 3/8 to 5/8 inch long. Together the husk and seed constitute the fruit -- a dry achene.

FORAGE VALUE

Bitterbrush is the most important range browse east of the Sierra Nevada-Cascade Divide in California. It forms only a small part of the forage crop in some localities but in others it constitutes the bulk of the livestock feed. Some stands exceed 0.5 density. A stand of 0.2 density with twig growth averaging 7.5 inches long will yield about 900 pounds of dry forage per acre.

Experiments at the University of Nevada in 1909 showed that crude protein makes up about 13 percent of the dry weight of the young leaves and twigs. In feeding tests with sheep 82 percent of this protein was found to be digestible. These tests further showed that in 100 pounds of dry matter 9.72 pounds of protein, 62.50 pounds of carbohydrate, and 2.25 pounds of fat were digested. Experiments in 1942 at the Utah Agricultural Experiment Station showed 15 percent protein in the leaves and tender twigs in June and 10 percent in September. The high protein content of bitterbrush even in September indicates its value in offsetting protein deficiencies that develop on many western ranges after the herbaceous vegetation dries up. Bitterbrush is especially valuable on the range because it provides green forage 4 to 6 weeks longer in the fall than most of the bunchgrasses and herbs on the same site. Thus it adds to the length of the grazing season.

GROWTH AND REPRODUCTION

The seasonal growth of the mature bitterbrush plant is illustrated in table 1. It should be noticed that twig growth starts after flowering. The season's flowers and seeds are borne on short spurs from previous years' wood and not on the current shoots. The new shoots produce seeds the following season if protected from excessive grazing and if other conditions permit. Twig growth continues into the early part of September, providing succulent green forage late in the season. It has been observed that grazed bushes remain green longer than ungrazed ones, probably because grazing stimulates regrowth and because less water is lost from the grazed plant through transpiration.

TABLE 1. Seasonal growth and development of bitterbrush, Halls Flat, Lassen National Forest, 1942

Stage	Month							Development period
	May	June	July	Aug.	Sept.	Oct.	Nov.	
Leaves growing	xx							May 8 - 20
Plants flowering		xxx						June 1 - 20
Twigs growing		xxxxxxxxxxxxxxxxx						June 10-Sept. 6
Seeds ripe and falling				xx				Aug. 1 - 10
Leaves falling						xxxxxxxxxxxxx		Sept.-Nov.

The seedlings emerge from the ground in the spring at about the time the parent plants start to grow. They rarely get to be more than 2 or 3 inches tall by the end of the first season. Their roots, however, penetrate the soil to depths of 15 to 20 inches or more. Flowering of ungrazed plants starts in the fourth or fifth year on some sites and 2 or 3 years later on others. At this stage the plants have a spread of about 8 to 10 inches and are 10 to 12 inches high. Seed production usually does not occur in appreciable quantities until the plants are 10 years old or older and have attained considerable size.

A comparison of the number of annual rings with the known age of plants indicates that the stems of bitterbrush form one growth ring a year. If rings have not been destroyed the age of dominant plants can be determined within 2 or 3 years by counting the rings in a section through the main stem at the ground line. The oldest stem examined by the writer had 82 rings. The life span of bitterbrush is probably between 60 and 70 years.

Bitterbrush reproduces mainly from seed. Occasionally, after injury of the crown by fire, chopping, or crushing, it sprouts from some of the numerous adventitious buds located near the base of the main stems, but this is not an important means of propagation of the plant. Only two instances of sprouting after burning have been observed in California, one near Delleker on the Plumas National Forest and one near Big Pine on the Inyo National Forest.

Factors Influencing Growth and Reproduction

Rodents.--Widespread observations and measurements by the writer indicate that most of the plants in bitterbrush stands become established from seeds cached by rodents. Upon germination the seeds produce a thick cluster of seedlings which form a single crown (fig. 4, A and B). The size and shape of this crown resembles that of a single older bitterbrush plant. This similarity may have led to the widely prevalent but erroneous idea that practically no seedlings were present in some localities.

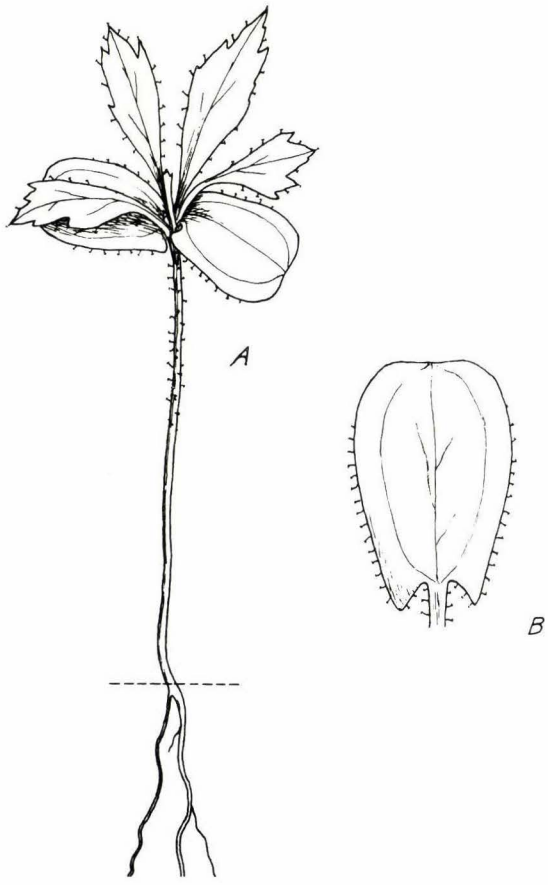

Fig. 3. A, Bitterbrush seedling, 1 month old; B, cotyledon of seedling.

A B

Fig. 4. A, A cluster of bitterbrush seedlings germinating from a rodent seed cache; B, the seedlings shown in A partly excavated and spread out to show numbers.

In a stand on the Lassen National Forest 58 percent of all the bitterbrush crowns were made up of two or more plants (table 2). No doubt many of the single plants in the stand were also part of rodent caches originally, since many caches are reduced to one surviving plant. The bitterbrush stand shown in table 2 has a uniform distribution of sizes, indicating that reproduction has become established at relatively frequent intervals.

TABLE 2. Number of plants per crown in a lightly grazed bitterbrush stand, Crater Mountain, Lassen National Forest, 1941

Plants per crown	Number of crowns[1/] by approximate diameter of stems of plants - inches							Total	Percent
	1/16	1/8	1/4	1/2	1	1½	2	2½	3		
1	13	8	3	7	12	6	3			52	42
2	1	3	4	6	9	2	2			27	22
3			5	2	2	2				11	9
4		1	2	3	4					10	8
5		1		2	4					7	6
6	1	2	2		2					7	6
7				1	1					2	1
8	1	1								2	1
9			1							1	1
10	1				2					3	2
11	1									1	1
17		1								1	1
Total	18	17	17	21	36	10		5		124	
Percent	14	14	14	17	29	8		4			100

1/ In a sample plot 3.3 ft. by 330 ft.

The caches are found buried from 1/4 to 1-1/2 inches below the surface of the soil and contain seeds, not fruits. Not all of the seeds in a cache germinate; the number germinating varies from 2 to over 100. In one cache 139 seedlings were found. Most of the caches are located in the spaces between shrubs where light is favorable for the establishment and survival of the seedlings. Seedlings under or around the edges of the crowns of older plants do not survive. It is rare to find a plant with a stem as large as 1/2 inch in diameter growing under an older plant.

The caching of bitterbrush seeds by rodents has not been actually observed, but it is suspected that chipmunks and golden-mantled ground squirrels do most of the caching. These rodents have been seen digging into the base of germinating seedlings in the spring in search of ungerminated seed. Mice also probably cache many of the seeds, but other seed-caching rodents are too scarce to account for much of the planting that occurs. A representative of the Fish and Wildlife Service concurred in these initial observations after a brief field check.

Chipmunks eat large quantities of the ripening seed. The sticky red juice of the seed coat, which remarkably resembles blood, gets on their feet and can be found smeared on rocks, sticks, logs, stumps, fence posts, stems of shrubs, and even on tree branches 5 or 6 feet above the ground. The amount of red juice on these objects roughly indicates the degree of rodent activity and the amount of bitterbrush seed produced during the season in a given area. Evidence of rodents' eating bitterbrush seeds is found almost everywhere during summer and fall. The remains of fruits and seed coats may be seen on rocks, logs, and stumps. Only the embryos of the seeds are eaten.

As seed-caching sites, rodents prefer soft, loose, or recently disturbed soils such as road shoulders, road banks, borrow pits, and areas disturbed by logging. The deep duff and litter at the base of pine trees is a favored planting site. Seedlings may be found there when they cannot be located elsewhere in the vicinity.

The amount of caching varies from year to year depending primarily on the amount of seed produced. In 1941 large numbers of caches were found on experimental plots. In 1942 there were very few. In 1943 germinating seed caches could be found by the thousands throughout the eastside region in lightly grazed stands. It is interesting that practically no caches were found in several dense stands of very large plants -- 6 to 12 feet tall -- on the Shasta, Lassen, and Mono National Forests, in spite of heavy seed production.

Rodents are detrimental as well as beneficial to bitterbrush. Plants have been observed to be killed by girdling of the stems during the winter, probably by mice. This cause of mortality is reported to be prevalent in parts of Oregon, Idaho, and Nevada, and further observation may reveal it to be more widespread in California than it now appears. It is doubtful however, if bitterbrush could perpetuate itself on California ranges without rodents in the face of the many factors that act to destroy the stands.

Destruction of seed-caching rodents would be detrimental to the propagation not only of bitterbrush but perhaps of other important forage species. Seeds of Idaho fescue (Festuca idahoensis), squirreltail (Sitanion hystrix), needlegrass (Stipa occidentalis), downy chess (Bromus tectorum), squaw mat (Ceanothus prostratus), snowberry (Symphoricarpos sp.), greenleaf manzanita (Arctostaphylos patula), Jeffrey pine, and unidentified species of forbs have been found in rodent caches. No doubt rodents cache the seed of many other important range and forest species. In 1943 a large part of the Jeffrey pine reproduction observed in the eastside region germinated in rodent caches. Several species often grow in the same cache. Bitterbrush and Jeffrey pine seedlings frequently occur together. Seedlings in rodent caches are conspicuous in the spring on burned areas and on dirt roads that were graded in the fall.

Livestock grazing.---Continuous heavy grazing by livestock season after season is probably the main cause of the widespread deterioration of bitterbrush on ranges. Heavy grazing is harmful primarily because it removes most of the twigs that bear the flowers and seeds and tends to kill the established seedlings and older plants in the stand.

If heavy grazing starts when the plant is young and persists for several years, bitterbrush acquires a prostrate mushroomlike shape (fig. 5). If heavy grazing starts when the plants are well grown, they become rounded back, lobed, or club-shaped, but they remain taller than the prostrate form. These cropped-back plants often live for a long time because the dense woody twig stubble left from previous years protects about 15 to 20 percent of the foliage from grazing.

Club-shaped and mushroom-shaped plants usually occur on heavily grazed ranges or where the stands are thin and the plants widely scattered. They are more prevalent on heavily grazed cattle ranges than on heavily grazed sheep or deer ranges because cattle eat not only the current twig growth but also woody branches as large as one-fourth of an inch in diameter. They tend to graze the plants more heavily on the top than sheep or deer graze them, and the plants are often kept down to a height of 1 or 2 feet. Sheep and deer, on the other hand, confine their grazing mainly to the current year's growth, frequently stripping off only the leaves and rarely utilizing the woody growth of previous years. A few shoots usually remain ungrazed and eventually some of the branches grow even beyond reach of the animals. These plants maintain an open straggly form (fig. 6). Apparently they do not maintain their vigor under heavy grazing as well as cropped-back plants because most of the foliage is removed, but they do ripen some seeds.

The palatability of this browse varies in different plants and with stage of growth, degree of use, and site location. Many stockmen and range technicians say that previously ungrazed bitterbrush is only lightly grazed by cattle or sheep. They believe that the plant has to be grazed at least moderately each year to remain palatable to livestock. Sharp dead twigs on the plant are known to hinder sheep grazing. A clearer understanding of the causes of variations in palatability of bitterbrush is necessary for the efficient management of the plant.

From present observations it is estimated that about 40 percent of the twig growth should remain on the bitterbrush plant each season to maintain plant vigor and to insure adequate seed production. Where bitterbrush makes up 25 percent or more of the forage and is heavily grazed, a reduction in livestock numbers will probably increase its vigor and reproduction. However, where bitterbrush makes up only a small part of the forage, even light grazing of the range as a whole will result in close use of the plant because of its high palatability. On these ranges, as well as where the shrub is more abundant, a system of deferred and rotation grazing that protects a portion of the range from use for an entire season every 4 or 5 years would probably provide the necessary twigs for maintaining high plant vigor and an abundant seed supply.

Deer grazing.--In certain localities winter use of bitterbrush by mule deer is heavy and summer use is light to moderate. Columbian black-tailed deer and antelope also graze bitterbrush but primarily in spring and summer.

Bitterbrush stands grazed by mule deer in winter and by livestock in summer show marked signs of deterioration. The winter use by deer is sometimes greater than the summer use by livestock. Satisfactory management of bitterbrush depends in part on knowing the relative effect of these different seasons of use on vigor and reproduction of the plant. Bitterbrush occurring in sparse stands may be grazed sufficiently by deer alone to prevent adequate seed production.

Defoliation by caterpillars.--Defoliation of bitterbrush by the Great Basin tent caterpillar frequently kills the plant or greatly reduces its vigor. The Forest Insect Laboratory, Bureau of Entomology and Plant Quarantine, Berkeley, has studied the tent caterpillar for several years and found that infestations occur over large areas throughout the range of bitterbrush and vary in severity from one year to the next and from one locality to another.

Epidemics are usually controlled within 2 or 3 years by natural causes such as the increase of insect enemies. The tent caterpillar can be killed in both egg and caterpillar stages by the use of insecticides, including light penetrating oils, that are nonpoisonous to livestock and the plant. However it is not economically feasible or practical to treat extensive range areas by these means to effect control of the insect.

The writer has observed that plants weakened by grazing or by previous caterpillar infestations may be seriously damaged or killed by a single heavy defoliation. Plants not weakened by such causes will often recover quickly after a heavy attack by caterpillars. Removal of 50 percent or more of the leaves by caterpillars reduces or prevents flower production the following season, even in vigorous plants. This suggests that grazing by livestock of more than half the foliage during the season will impair seed production.

Burning.-- Hundreds of thousands of acres of bitterbrush have been destroyed by fire. Fire is especially harmful because it kills the plant and creates conditions that make it difficult for reproduction to become reestablished.

The fact that only occasional seedlings germinate on burned areas the year after burning indicates that most of the seeds have been destroyed. Furthermore, dense stands of downy chess (Bromus tectorum) usually invade these burns and retard the establishment of bitterbrush seedlings by shading them and competing with them for moisture. Rodents do not cache seeds abundantly in areas covered by downy chess.

Bitterbrush becomes reestablished on burns primarily from seed buried by rodents. A stand of bushes 2 or 3 feet tall can become established on a small burn on a favorable site in about 15 years if rodents

Fig. 5. Shape of bitterbrush characteristic of heavy grazing, particularly by cattle.

Fig. 6. Form of bitterbrush characteristic of heavy grazing by sheep or deer. Note the flowers on the upper lightly grazed part of the plant.

cache seeds the same year or the year after the fire. Seed caches have been found 200 yards inside burns. It takes many years for bitterbrush to reclaim large burns even with the aid of rodents. But without rodents the burns would not be revegetated by bitterbrush in hundreds of years — if at all.

Weather and other factors.--No doubt weather interferes with the growth and reproduction of bitterbrush at critical growth stages. Often mentioned as causing or contributing to the death of bitterbrush are drought, freezing or sudden extreme changes in temperature, poor soil drainage, or a temporary rise in the water table. Portions of the plant above the snow have been killed by freezing. Bitterbrush seeds fail to develop in some years, owing, it is believed, to unfavorable weather. Seed formation is also prevented by insects that burrow into the developing flower. Galls and rusts on the leaves and stem decay may contribute to the mortality of the shrub.

ARTIFICIAL REVEGETATION

Artificial revegetation offers considerable promise of getting bitterbrush reestablished on many areas where it has been destroyed. The following suggestions are based on experiments and observations to date.

Collection, Storage, and Viability of Seed

Ripe seeds can be collected in July or early August. They should be plump and grayish in color and the red juice in the seed coat should be well solidified. The seeds should be collected from the part of the plant that is producing ripe seed. They mature first on the lower branches and last on the upper and may be stripped off the branches by hand if gloves are worn. The seeds usually fall to the ground within 4 or 5 days after ripening and therefore the collecting time should be closely watched.

It is best to store the seeds in a cool, dry place, preferably in tin containers, until they are used. Seeds stored at 41° F. for 3 years retained most of their initial viability.

The viability of seeds can be tested in a few days in a sample of about 100 seeds from which the embryos have been removed and germinated on blotters or moist sand at temperatures above 55° F. The viable embryos will start to grow in about 2 or 3 days. The embryo can be removed after the seed has been soaked in water for about 4 hours to soften the seed coat. A cut is made with a sharp razor through the top of the seed between the cotyledons to a point just below the widest part of the seed. After the seed coats are pried back from the cut, the embryo can be forced up through the opening when the root end of the seed is gently squeezed.

Fresh seeds that have a well-developed white embryo are usually viable. The embryo can be seen when the seeds are cut in half.

Time of Planting and Seed Treatment

Bitterbrush may be sown in either the fall or the spring. Fall plantings can be made at any time from September until snow covers the ground. Spring plantings should be made early -- from the time snow leaves the ground until the established bitterbrush plants in the vicinity start to put out their first leaves. The soil should not be dried out more than half an inch below the surface.

Either seeds or fruits may be sown in the fall, but in the spring it is best to use stratified seeds. Stratification consists of storing the seeds in coarse wet sand at temperatures between 32° F. and 41° F. for 5 to 8 weeks. When stratified seeds are planted in the field under favorable moisture and temperature conditions they emerge from the ground in 10 to 20 days. In the laboratory stratified seeds gave 60- to 80-percent germination and unstratified seeds gave less than 20-percent germination at temperatures of about 70° F.

Apparently the low temperatures during stratification induce germination. Seeds or fruits planted in the fall, like the fruits that drop to the ground naturally or the seeds that are buried by rodents, are stratified by the low temperatures that prevail from fall to spring. Experimental evidence indicates that stratification in the field takes place mainly during the spring after the snow melts and temperatures rise above freezing. It is probable therefore that unstratified seeds planted early in the spring just after the snow melts would germinate in appreciable numbers.

Stratified fruits gave considerably less germination than stratified seeds in the laboratory. The husk of the fruit seemed to interfere with germination. Experimental planting of fruits in September gave high germination the following spring, however. This suggests that the husks were decomposed sufficiently in the 5 or 6 months from fall to spring to permit germination. Spring planting of unstratified fruits is not recommended, since it is unlikely that the fruit husks would be broken down sufficiently in 1 or 2 months to promote appreciable germination.

Seeds stratified at 41° F. show signs of sprouting after 5 or 6 weeks. They should be removed for planting at this time because if the sprouts are allowed to get much longer they are likely to be broken off in handling. To prevent further sprouting while the seeds are being transported and handled in the field they should be packed in ice. They may be kept in this way for a week to 10 days.

Depth and Method of Planting

In both spring and fall the seeds should be planted 1/4 to about 1 1/4 inches deep in the soil. They may be sown broadcast and disked or harrowed into the ground or they may be planted in shallow furrows or in spots by hand or with a corn planter. The most practical method will depend on ground conditions -- on degree of slope, the amount of rocks and vegetation, down logs, and other obstructions.

Survival of Seedlings

The results from both fall and spring experimental plantings indicate that if either seeds or fruits are sown at the proper depth and at the proper time only a small percentage is likely to be found and destroyed by rodents. More than half of the seeds can be expected to germinate. However, many of the young seedlings are destroyed by rodents, insects, game, or unfavorable weather during the first month of growth. This loss occurs usually before the livestock-grazing season starts. Even under favorable conditions as many as 90 percent of the seedlings may die by the beginning of the third year of growth. It is estimated that less than 5 percent of the planted seed will produce mature plants. In artificial reseeding enough extra seed should be sown to offset this high mortality. The number of seedlings to survive will depend on the site — on the moisture-holding capacity of the soil, the amount of spring and summer rain, and the amount of vegetation competing with the seedlings the first season or two when they are developing their root systems.

Selection of Planting Site

Reseeding of bitterbrush should be tried first on areas that are known to have supported bitterbrush in the past or still support some of the plants. Within the range of bitterbrush the chances of getting successful establishment of seedlings from artificial reseeding differs from one place to the next. The ages of the plants in ungrazed or lightly grazed bitterbrush stands, near and comparable in site to one proposed for planting, can be used as a guide in judging the suitability of a particular area for reseeding. If the plants in these stands range in age from young to old and differ in age by only 1 or 2 years it shows that seedlings have become established at frequent intervals in the past. This indicates that the chances of survival of at least some of the seedlings from plantings on the site would be high. On the other hand if the number of years between age groups is large, 5 or more years, the odds against seedling survival would be 5 or more to 1. The ages of the plants in a stand used to get an indication of seedling survival can be determined by counting the annual rings in the stems of plants on sample strips about 18 inches wide and 4 or 5 chains long. The plants should be pulled up by the roots and the stems sectioned for the ring counts.

Artificial reseeding is always a gamble primarily because of the uncertainty of weather, but careful selection of the planting site will increase the chances of success. Until more is known about the subject bitterbrush reseeding should be carried out on a small scale on sites that are most favorable for seedling establishment.

Intensity and Coverage of Planting

There are from 18,000 to 24,000 seeds and about 14,000 to 20,000 fruits in a pound. In broadcast planting 2 pounds of seed or 3 pounds of fruit per acre seems adequate. This provides one seed for each square foot or two of ground surface. In spot planting 4 or 5 seeds may be sown

in one place at intervals of 4 or 5 feet along lines spaced 4 or 5 feet apart. In furrow planting 1 or 2 seeds should be distributed over each linear foot of line.

Rodents are known to carry seed as far as 200 yards from the nearest bitterbrush plants, but they cache intensively usually within only 100 feet of the seed supply. Therefore planting-strips 10 to 20 feet wide spaced about 200 feet apart should provide ample plants and seeds for future caching in the interspaces.

SUMMARY

Bitterbrush is the most important range browse east of the Sierra Nevada-Cascade ranges in California. Over large areas it has been destroyed or damaged by such factors as fire, heavy grazing by livestock and game, defoliation by tent caterpillars, girdling by rodents, or weather conditions. Not enough reproduction is becoming established to perpetuate the stand in many places.

Bitterbrush reproduces mainly from seed and the stands are established chiefly from seeds buried in caches by rodents. The natural dissemination of bitterbrush seeds and the spread of the plant over wider areas is chiefly the result of rodent caching. The quick reestablishment of bitterbrush on many small burned areas is due to the caching of bitterbrush seed on these areas by rodents.

Close grazing by livestock each year is probably the principal cause of the widespread deterioration of bitterbrush in California. It is harmful primarily because it reduces the seed supply, preventing the establishment of sufficient young plants to maintain the stand. It is estimated that 40 percent or more of the twig growth should remain on the plant each season to insure adequate seed production and good plant vigor.

Heavy use resulting from winter grazing of bitterbrush by mule deer combined with summer grazing by livestock is damaging bitterbrush in some localities. Defoliation of bitterbrush by the Great Basin tent caterpillar also causes heavy destruction of bitterbrush. Plants weakened by grazing or previous caterpillar infestations are more easily killed by defoliation than plants not weakened by these causes.

Fire kills bitterbrush in most instances in California. Valuable bitterbrush stands should be given full protection from fire.

Artificial reseeding trials offer considerable promise for the reestablishment of bitterbrush on many sites where it has been destroyed. Germination from both fall and spring plantings can be expected in most years. However, survival of the seedlings depends also on adequate soil moisture throughout the first growing season and protection from rodent damage and heavy grazing. Survival may be expected on sites that adjoin areas where some natural reproduction has become established in most years.

Additional facts on growth, reproduction, utilization, and artificial reseeding of bitterbrush are needed for the satisfactory management of this valuable browse. Such information can be used to increase livestock production and improve the general condition of ranges.